Claims

1. A carbon nano-fibrous rod comprising:

a hexagonal carbon layer having a central axis extending in one direction.

2. The carbon nano-fibrous rod according to claim 1, characterized in that

an axial width (D) of the hexagonal carbon layer is 2.5±0.5 nm, and

a length (L) of the hexagonal carbon layer is 17±15 nm.

3. The carbon nano-fibrous rod according to claim 1 or 2, characterized in that

2 to 12 of the hexagonal carbon layers are stacked.

4. Fibrous nanocarbon comprising:

a plurality of the carbon nano-fibrous rods of any one of claims 1 to 3 gathered together.

5. The fibrous nanocarbon according to claim 4, characterized in that

the carbon nano-fibrous rods are stacked in a three-dimensionally close-packed state.

6. The fibrous nanocarbon according to claim 4 or 5, characterized in that

the plurality of the carbon nano-fibrous rods are stacked, with central axes thereof being parallel to each other, to constitute a carbon nano-fibrous rod cluster.

7. The fibrous nanocarbon according to claim 6, characterized in that

the carbon nano-fibrous rod cluster comprises the carbon nano-fibrous rods three-dimensionally stacked, with nano-gaps being provided between the carbon nano-fibrous rod comprising the 2 to 12 of the hexagonal carbon layers stacked and the carbon nano-fibrous rod comprising the 2 to 12 of the hexagonal carbon layers stacked.

8. The fibrous nanocarbon according to claim 4, characterized in that

the carbon nano-fibrous rods are joined in series at axial end portions to constitute a carbon nano-fibrous rod cluster in an axial direction.

9. The fibrous nanocarbon according to claim 8, characterized in that

the axial end portions of the carbon nano-fibrous rods are joined by heat treatment.

10. The fibrous nanocarbon according to claim 6, characterized in that

the carbon nano-fibrous rod cluster is arranged at an arrangement angle of larger than 0 degree but smaller than 20 degrees with respect to an axis perpendicular to a fiber axis in a direction of stack of the carbon nano-fibrous rods, thereby forming a columnar shape.

11. The fibrous nanocarbon according to claim 6, characterized in that

the carbon nano-fibrous rod cluster is arranged at an arrangement angle of larger than 20 degrees but smaller than 80 degrees with respect to an axis perpendicular to a fiber axis in a direction of stack of the carbon nano-fibrous rods, thereby forming a feather shape.

12. The fibrous nanocarbon according to claim 10 or 11, characterized in that

the carbon nano-fibrous rod cluster has a herringbone structure.

13. The fibrous nanocarbon according to claim 10 or 11, characterized in that

an interplanar distance (d_{002}) between the

hexagonal carbon layers is less than 0.500 nm under heat treatment conditions at 700°C or lower.

14. The fibrous nanocarbon according to any one of claims 10 to 12, characterized in that

a fiber width of an aggregate of the carbon nano-fibrous rods is 8 to 500 nm, and a fiber aspect ratio (fiber length/fiber width) of the aggregate is 10 or more.

15. The fibrous nanocarbon according to claim 8, characterized in that

the carbon nano-fibrous rod cluster is arranged at an arrangement angle of 80 degrees to 88 degrees with respect to an axis perpendicular to a fiber axis in a direction of stack of the carbon nano-fibrous rods, thereby forming a tubular shape.

16. The fibrous nanocarbon according to claim 15, characterized in that

a fiber width of an aggregate of the carbon nano-fibrous rods is 8 to 80 nm, and a fiber aspect ratio (fiber length/fiber width) of the aggregate is 30 or more.

17. The fibrous nanocarbon according to any one of claims 10 to 16, characterized in that

a cross sectional structure in a direction perpendicular to the fiber axis is polygonal.

18. The fibrous nanocarbon according to any one of claims 10 to 17,

characterized by being heat-treated at a high temperature of 1,600°C or higher, and

characterized in that ends of the carbon nano-fibrous rods on a surface of the fibrous nanocarbon are two-dimensionally loop-shaped and three-dimensionally dome-shaped.

19. A method for producing fibrous nanocarbon comprising an aggregate of carbon nano-fibrous rods by reacting a carbon material in a high temperature fluidized bed with use of a catalyst,

characterized by using, as a fluid material, a dual-purpose catalyst/fluid material comprising a metal catalyst-supporting carrier bound via a binder, and

characterized by performing

a first gas supply step of supplying a reducing gas,

a carbon material supply step of supplying the carbon material in a gaseous state to produce a carbon nano-fibrous rod in a presence of the metal catalyst of the dual-purpose catalyst/fluid material, and

a second gas supply step of supplying a carbon-free gas to eliminate a fluidizing function of the dual-purpose catalyst/fluid material.

20. The method for producing fibrous nanocarbon according to claim 19, characterized in that

an average particle diameter of the dual-purpose catalyst/fluid material is 0.2 to 20 mm.

21. The method for producing fibrous nanocarbon according to claim 19, characterized in that

the dual-purpose catalyst/fluid material comprises a product formed by supporting the catalyst on a surface of the carrier, or an agglomerate of the products.

22. The method for producing fibrous nanocarbon according to claim 19, characterized in that

the carrier of the dual-purpose catalyst/fluid material is any one of carbon black, alumina, silica, silica sand, and aluminosilicate.

23. The method for producing fibrous nanocarbon according to claim 19, characterized in that

the metal catalyst of the dual-purpose catalyst/fluid material is any one of Fe, Ni, Co, Cu and Mo, or is a mixture of at least two of these metals.

24. The method for producing fibrous nanocarbon according to claim 19, characterized in that

a flow velocity in the fluidized bed is 0.02 to 2 m/s.

25. The method for producing fibrous nanocarbon according to claim 19, characterized by

controlling conditions for each of the first gas supply step, the carbon material supply step, and the second gas supply step independently of one another.

26. The method for producing fibrous nanocarbon according to claim 25, characterized in that

the conditions are a temperature, a pressure, a time, and a gas atmosphere.

27. The method for producing fibrous nanocarbon according to claim 19, characterized by

bringing the catalyst of the dual-purpose catalyst/fluid material and the carbon material into contact with each other at a temperature of 300 to 1,300°C in a gas mixture of hydrogen and an inert gas (hydrogen partial pressure 0 to 90%) at a pressure of 0.1 to 25 atmospheres, thereby producing the fibrous nanocarbon.

28. The method for producing fibrous nanocarbon

according to claim 19, characterized by

metallizing and finely dividing the catalytic component of the dual-purpose catalyst/fluid material by a reducing action of the reducing gas in at least one of the first gas supply step and the carbon material supply step.

29. The method for producing fibrous nanocarbon according to claim 28, characterized by

controlling a particle diameter of the metal catalyst of the dual-purpose catalyst/fluid material in finely dividing the metal catalyst, thereby controlling a diameter of the fibrous nanocarbon obtained.

30. The method for producing fibrous nanocarbon according to claim 19, characterized in that

the second gas supply step forms a zone at a high flow velocity locally in the fluidized bed to promote fine division and wear of the dual-purpose catalyst/fluid material by a collision between particles of the dual-purpose catalyst/fluid material, or a collision between the particles and a wall surface.

31. The method for producing fibrous nanocarbon according to claim 30, characterized in that

the zone at a high flow velocity in the fluidized

bed is formed in a lower portion of the fluidized bed.

32. The method for producing fibrous nanocarbon according to claim 30, characterized in that

the zone at a high flow velocity is formed by flowing a high velocity gas into the fluidized bed.

33. The method for producing fibrous nanocarbon according to claim 32, characterized by

supplying particles, which have scattered from the fluidized bed, again into the fluidized bed while entraining the particles in the high velocity gas.

34. The method for producing fibrous nanocarbon according to claim 19, characterized by

separating the produced fibrous nanocarbon from the carrier or the catalyst.

35. An apparatus for producing fibrous nanocarbon, which is used in performing the method for producing fibrous nanocarbon according to claim 19, and comprising:

a fluidized bed reactor charged with the dual-purpose catalyst/fluid material and provided with heating means for heating an interior of the fluidized bed reactor;

first gas supply means for supplying the reducing

gas into the fluidized bed reactor;

carbon material supply means for supplying the carbon material in a gaseous state into the fluidized bed reactor;

second gas supply means for supplying the gas free from carbon into the fluidized bed reactor; and

a discharge line for discharging a gas and scattered particles from the fluidized bed reactor.

36. The apparatus for producing fibrous nanocarbon according to claim 35, characterized in that

recovery means for recovering the scattered particles is provided in the discharge line.

37. The apparatus for producing fibrous nanocarbon according to claim 35, characterized in that

a fluidized bed portion of the fluidized bed reactor has a high velocity flow portion and a low velocity flow portion.

38. The apparatus for producing fibrous nanocarbon according to claim 37, characterized in that

a collision portion is present in the high velocity flow portion.

39. The apparatus for producing fibrous nanocarbon according to claim 35, characterized in that

high velocity gas blowing means for blowing a gas at a high velocity into the fluidized bed reactor is provided.

40. The apparatus for producing fibrous nanocarbon according to claim 39, characterized in that

when the gas is blown at a high velocity, recovered particles are entrained in the gas.

41. The apparatus for producing fibrous nanocarbon according to claim 35, characterized in that

a first flow chamber, a second flow chamber, and a third flow chamber, where the fluid material is flowingly movable, are formed within the fluidized bed reactor,

the first gas supply means is connected to the first flow chamber,

the carbon material supply means is connected to the second flow chamber, and

the second gas supply means is connected to the third flow chamber.

42. The apparatus for producing fibrous nanocarbon according to claim 35, characterized in that

a first flow chamber and a second flow chamber, where the fluid material is flowingly movable, are formed within the fluidized bed reactor,

another fluidized bed reactor different from the fluidized bed reactor is provided as a third flow chamber,

transport means for transporting the fluid material from the second flow chamber to the third flow chamber is provided,

the first gas supply means is connected to the first flow chamber,

the carbon material supply means is connected to the second flow chamber, and

the second gas supply means is connected to the third flow chamber.

44. An apparatus for producing fibrous nanocarbon, which is used in performing the method for producing fibrous nanocarbon according to claim 19, and comprising:

a first fluidized bed reactor charged interiorly with the dual-purpose catalyst/fluid material, having heating means for heating an interior of the first fluidized bed reactor, and having first gas supply means for supplying the reducing gas into the first fluidized bed reactor;

a second fluidized bed reactor having transport means for transporting the fluid material from the first fluidized bed reactor, and having carbon material supply means for supplying the carbon material in a

gaseous state into the second fluidized bed reactor;

a third fluidized bed reactor having transport means for transporting the fluid material and a reaction product from the second fluidized bed reactor, and having second gas supply means for supplying the gas free from carbon into the third fluidized bed reactor; and

a discharge line for discharging a gas and scattered particles from the third fluidized bed reactor.

45. The apparatus for producing fibrous nanocarbon according to claim 44, characterized by

including a plurality of the first fluidized bed reactors.

46. The apparatus for producing fibrous nanocarbon according to claim 44, characterized by

including a plurality of the second fluidized bed reactors.

47. The apparatus for producing fibrous nanocarbon according to claim 44, characterized by

including a plurality of the third fluidized bed reactors.

48. The apparatus for producing fibrous nanocarbon

according to any one of claims 35 to 47, characterized in that

an average particle diameter of the dual-purpose catalyst/fluid material is 0.2 to 20 mm.

49. The apparatus for producing fibrous nanocarbon according to any one of claims 35 to 47, characterized in that

the dual-purpose catalyst/fluid material comprises a product formed by supporting the catalyst on a surface of the carrier, or an agglomerate of the products.

50. The apparatus for producing fibrous nanocarbon according to any one of claims 35 to 47, characterized in that

the carrier of the dual-purpose catalyst/fluid material is any one of carbon black, alumina, silica, silica sand, and aluminosilicate.

51. The apparatus for producing fibrous nanocarbon according to any one of claims 35 to 47, characterized in that

the metal catalyst of the dual-purpose catalyst/fluid material is any one of Fe, Ni, Co, Cu and Mo, or is a mixture of at least two of these metals.

52. The apparatus for producing fibrous nanocarbon according to any one of claims 35 to 47, characterized in that

a flow velocity in the fluidized bed is 0.02 to 2 m/s.

53. The apparatus for producing fibrous nanocarbon according to any one of claims 35 to 47, characterized in that

the catalyst of the dual-purpose catalyst/fluid material and the carbon material are brought into contact with each other for a certain period of time at a temperature of 300 to 1,300°C in a gas mixture of hydrogen and an inert gas (hydrogen partial pressure 0 to 90%) at a pressure of 0.1 to 25 atmospheres, whereby the fibrous nanocarbon is produced.